The Quantum Leap
November 24, 2021

Follow the Money…the Quantum Computing Goldrush

You're likely thinking to yourself, "OK, I see there is some potential in Quantum Computers, and some theoretically important use cases, but nobody has created a robust working Quantum Computer…existing qubits only stay coherent for milliseconds at best, so isn't this all just hype?"

While no one can say for sure, my suggestion, paraphrasing Deep Throat's instructions to Bob Woodward, is to **"follow the money."**

The amount of funding being dedicated to Quantum Computing on a global basis is staggering. Governments, private companies, venture firms and academic institutions are all committing huge sums of money and resources to this field. While investment flows are no guarantee of future value, there is a broad common theme to push the development of Quantum Computers, and the equivalent of the modern "space race" is garnering growing attention in the media. Given the awesome power, potential and disruption that Quantum Computers can deliver, these trends should not be surprising.

The industry is at an interesting crossroad, where it has evolved from being an esoteric theoretical construct, to having many dozens of firms and academic institutions creating actual working (albeit still not very powerful) Quantum Computers. The challenge now is an engineering one, not a theoretical one. And with the growing pull of resources, it should be expected that engineering challenges will be overcome, and developments will accelerate.

When integrated circuits were still being created in the 1950's, very few people could have imagined the boon it would create. Things like personal computers, cellular phones or the Internet were not yet contemplated. Even when PCs were made available in the early 80's, many were skeptical that there was an actual market for such an esoteric device. In fact, here is a reprint of an editorial by William F. Buckley Jr. as printed in the *Lancaster New Era* on July 19, 1982, where he is mulling that he cannot fathom any possible way a personal computer could be useful in the home:

WILLIAM F. BUCKLEY Jr.

Do We Really Need Home Computers?

Stanley Marcus, the famous merchandiser responsible for the success of Dallas' Neiman-Marcus, said recently that the art of selling is dead in America. Two years ago he took a pledge not to buy anything ever again on his own initiative. He would henceforth buy only things that were sold to him.

Buckley

In any case, Mr. Marcus said that it worked out that he hadn't bought a thing in two years, and has therefore saved himself $43,000 per year, the annual average cost of Mr. Marcus' predatory appetite.

In conversation with an executive of IBM the other day I said that I hoped before I died that someone — anyone — would devote a page of advertising now given over to home computers to explaining exactly how a computer can be useful — in the home. One's own imagination tends to be limited in these matters. I know of one use to which I would myself wish to put a home computer, but yearn to know of others, since it is difficult to believe that $1.5 billion is being spent idly by American homeowners.

I'd like one that would hold the contents of a large dictionary, so that I could type out the word "otiose" and be reminded of what it meant. I said be reminded of what it meant because a communicable aphasia hit me when I was 16. At that time a teacher told his class that most people have two or three words whose meaning they are forever forgetting, and he gave as his example the word otiose. I swooped upon a dictionary a half-hour later and learned what it meant.

Since then I have probably looked the word up 30 times. At this moment, I can't remember what I means. I don't suppose, though, the crowds will storm the store that advertises: "Learn instantly what otiose means!"

William Draper, the president of the Import-Export Bank and an investor in small computers, told me once: "Software is everything. There are no remaining problems of hardware." It took awhile before I understood that, which however I am now prepared to explain. What he meant was that the machine exists into which you can program the whole dictionary, or for that matter the whole encyclopedia. But somebody has got to pay for the time of the person who types out the 400,000-odd entries in Webster's Third into the discs that you then insert into the machine.

Moreover, the capacity of the machine to memorize increases with some reference to its cost. A machine that operates a disc that will memorize, let us say, 64 bytes will give you 64,000 characters. Since the average word has five characters, then the disc is good for about 10,000 words, or about 12 times the length of this article.

You can get a second disc — and a third — and a 300th. And the hardware exists that will search through your discs until it lands on "otiose." But by that time you have run out of money and run out of time; so you resign yourself to the dictionary.

Stanley Marcus is on to something. Some gadgets we know instinctively how to put to use: radios, say, or Waring blenders. But a $1,000 computer? The Pulitzer Prize belongs to the man who reveals what they're good for. I mean, what they're good for that the average newspaper reader wants to know.

Not surprisingly, his point-of-view is strictly in the context of the written word, since he is a writer, so his myopia makes contextual sense. Given that Quantum Computers are based on a completely different set of physics, logic gates and architecture, I am confident that the use cases will expand well beyond any currently contemplated uses and that current skeptics should try to maintain an open mind.

Government Directed Quantum Computing Investments

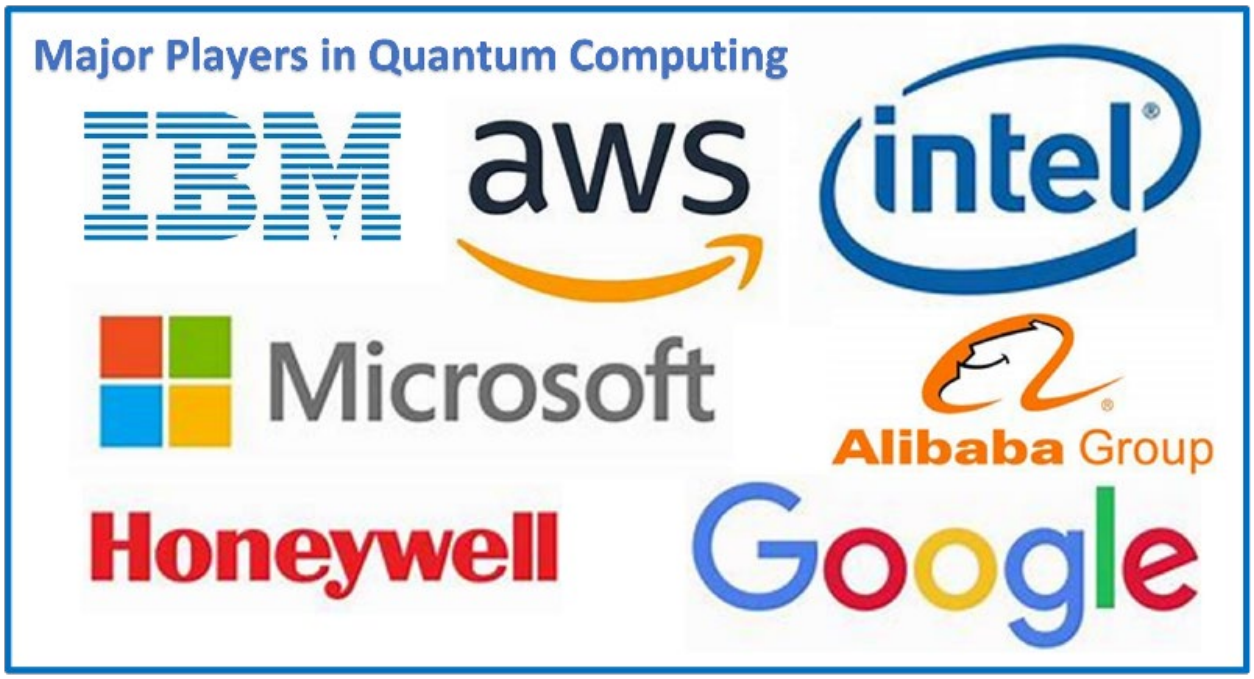
As can be seen in the chart below, the top ten countries focused on Quantum Computing technology have recently invested or committed over $21 billion towards this field:

Country	Commitment	Comment
The United States	$1.2 billion	National Quantum Initiative announced in 2019 with 5-year plan.
	$1.0 billion	Consortium of government agencies creates fund to establish 12 AI and quantum information research centers nationwide.
	$80m	Department of Energy commitment.
China	$10 billion	In 2018 China announced a $10B investment in the National Laboratory for Quantum Information Sciences.
Canada	$1 billion	Est. amount invested directly by the government over the past 10 years. Additional amounts via public-private partnerships.
The United Kingdom	$1.3 billion	Beginning in 2013, the UK became first European country to announce its own quantum strategy.
Germany	$725 million	In 2018 the German government pledged this amount over a four-year period.
	$2.25 billion	Angela Merkel recently announced further funding towards a quantum technology innovation program.
France	$2.0 billion	President Macron laid out a national five-year strategy to finance research in quantum technologies.
India	$1.1 billion	2020 announcement to fund the National Mission on Quantum Technologies and Applications over a five-year period.
Russia	$790 million	The government is establishing a National Quantum Laboratory.
Japan	$270 million	A ten-year plan to fund Quantum Computing technology.
South Korea	$40 million	The government announced a five-year plan in 2019 to develop proprietary core Quantum Computing technology.
TOTAL	**$21.75 billion**	**Top ten country's commitments**

The breadth and depth of these commitments are catalyzing the industry and I expect these trends to continue, so even excluding private company investment, there will be significant advancements achieved at the national level.

Some Major Current Players

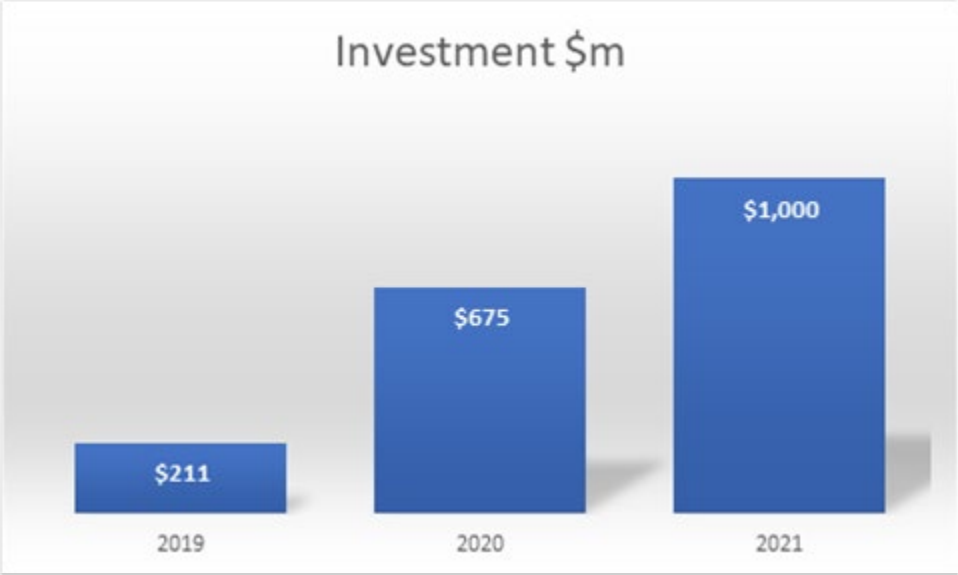
Some of the largest players in the technology space have already dedicated large departments or divisions to Quantum Computing, and lead the push to broad adoption, as highlighted below:



Many are already offering their own quantum software platforms and providing early access to prototype machines over the web. For example, anyone can download the IBM Qiskit open-source Quantum Software Development Kit (SDK), create programs, and run them on an IBM quantum emulator. Similarly, you can download and run Google's Cirq, Microsoft's Azure, Alibaba's Aliyum, etc. among others. These firms are leveraging their broad infrastructure, technological resources, and established web-based platforms to advance the access to, and utilization of, evolving Quantum Computing resources. In addition, in June **Honeywell** agreed to invest $300 million in its Quantum Computing unit after it merged with **Cambridge Quantum Computing**.

Venture Investment in Quantum Computing

rowing and accelerating focus on Quantum Computing among venture investors. According to the *Quantum Computing Report*, there have been **more than 450 venture investments** in Quantum Computing companies made by **more than 300 different venture investment firms**. Echoing the growth of Silicon Valley companies funded by legendary Sand Hill Road venture investors, current venture investors are making increasing large and diverse bets on many parts of the Quantum Computing ecosystem. The following chart showcases aggregate venture investments in each of the past three years (with more than a month still left in 2021):



A few venture firms have focused on Quantum Computing investments, with 17 firms making 3 or more such investments and with two (Quantonation and DCVC) making 10 or more each, as highlighted in the following table:

Venture Investor	# Deals	HQ
Quantonation	13	France
DCVC (Data Collective)	11	USA
Bloomberg Beta	9	USA
S28 Capital	8	USA
High-Tech Gründerfonds	5	Germany
Oxford Sciences Innovation	5	UK
In-Q-Tel	4	USA
WorldQuant Ventures	4	USA
Airbus Ventures	3	USA
Entrepreneur First (EF)	3	UK
IP Group	3	UK
Main Sequence	3	Australia
OurCrowd	3	USA
Parkwalk	3	UK
Runa Capital	3	USA
SGInnovate	3	Singapore
Summer Capital	3	Netherlands

The following highlights some of the larger announced venture investments:

Company	Funding	Investor(s)
PsiQuantum	$509 million	BlackRock, Blackbird Ventures, Founders Fund, Temaskek, others
IonQ	$350 million	Silver Lake, NEA, Fidelity, others
D-Wave	$228 million	NEC
Rigetti	$186 million	Bessemer, Frankilin Templeton, T.Rowe Price, others
Xanadu	$141 million	Bessemer, Radical Ventures, Capricorn, In-Q-Tel, others
ColdQuanta	$69 million	Foundry Group, GrayArch, Maverick, Global Frontier, others
1Qbit	$68 million	Canada Digital Tech, Granpool, Fujitsu, others
Zapata Computing	$64 million	Comcast Ventures, Alumni Ventures, Itochu, Pitango, others

Sources: PitchBook, Boston Consulting Group

Of these companies, **IonQ** became the first-ever pure-play Quantum Computing company to go public, debuting on the NYSE on October 1, 2021, and as of Nov. 23rd had a market capitalization of **$4.8 BILLION**. **Rigetti Computing** also recently announced it would be going public in an expected $1.5 billion reverse merger with a SPAC. The latest **PsiQuantum** investment was announced this past summer and included a $450 million investment at a valuation exceeding $3 billion, with ambitious plans to build a commercially viable Quantum Computer by 2025.

University Focus on Quantum Computing

Quantum computing and quantum information theory has gone from being a fringe subject to a full complement of classes in well-funded programs at quantum centers and institutes at leading universities. Some world-class universities offering dedicated Quantum Computing classes and research efforts include:

· *University of Waterloo—Institute for Quantum Computing*

· *University of Oxford*

· *Harvard University—Harvard Quantum Initiative*

· *MIT—Center for Theoretical Physics*

· *National University of Singapore and Nanyang Technological University—Centre for Quantum Technologies*

· *University of California Berkeley—Berkeley Center for Quantum Information and Computation*

· *University of Maryland—Joint Quantum Institute*

· *University of Science and Technology of China—Division of Quantum Physics and Quantum Information*

· *University of Chicago—Chicago Quantum Exchange*

· *University of Sydney, Australia*

· *Ludwig Maximilian University of Munich—Quantum Applications and Research Lab*

· *University of Innsbruck—Quantum Information & Computation*

These Colleges and Universities, as well as many others, continue to add courses and departments dedicated to Quantum Computing.

We are witnessing an unprecedented concentration of money and resources focused on Quantum Computing, including substantial government initiatives, major industrial player focus, accelerating venture investment and evolving university programs. While not all investments will be positive, and the landscape continues to evolve, serious, smart money is backing this trend. The clear message is that resource focus will lead to engineering breakthroughs and immense value creation. There are now 100's of companies jockeying for position in this evolving field. Stay tuned to this blog as we watch for the winners and losers.

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Russ Fein is a venture investor with deep interests in Quantum Computing (QC). For more of his thoughts about QC please visit the link to the left. For more information about his firm, please visit Corporate Fuel. Russ can be reached at russ@quantumleap.blog.